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Virtual Heritage Learning Environments

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Abstract. The change and restrictions in how we react with cultural heritage because of the COVID-19 pandemic has created an urgency in advancing remote and digital access to objects and sites. This paper outlines the process for developing Virtual Learning Environments (VLEs) using digital recording and modelling of architectural heritage and archaeology. Virtual Reality (VR) software, game engine platforms and WEB platforms are outlined which can be applied to represent heritage sites in addition to emerging screen based technological learning systems. The application Historic Building Information Modelling (HBIM) and Game Engine Platforms for creating Virtual Learning Environments (VLEs) is also examined. The design-theory based on Virtual Learning Objects for cultural heritage is explored. Two case studies are explored for their potential to create Virtual Heritage Learning Environments. Finally, a design framework is proposed for developing Virtual Heritage Learning Environments.

Keywords: First Keyword, Second Keyword, Third Keyword.

1 Virtual Learning and Digital Heritage

1.1 Introduction

The reduced access to cultural heritage sites in response to the COVID-19 crisis has created an increased demand for alternatively accessing virtual representations of historic buildings and their environments, consequently, it is necessary to enquire.

1. What are the most suitable tools and design systems?
2. What the implications are for education in conservation and valorization of cultural heritage?

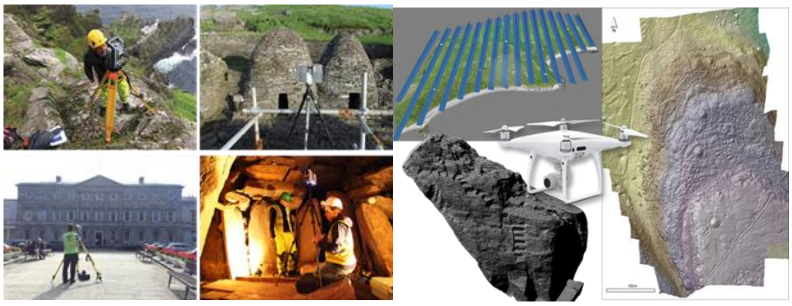

Fig. 1. Digital Recording and Surveying Heritage Sites in Ireland (Discovery Programme)

Virtual Reality (VR) software, game engine platforms and WEB platforms are now commonly applied to represent heritage sites and are enhanced with the use of handheld devices and ubiquitous computing. The emerging screen based technological learning systems are also a contributing factor. In parallel the digital automation for surveying and recording heritage objects and environments has resulted in large and very useful data sets from GPS, laser scanning and digital photogrammetric surveys. This survey data when used for archaeology and architectural heritage is enriched with the addition of knowledge and information content attached as semantic attributes to a digital object. Digital objects then move from static to dynamic representations and can then be used for information and knowledge sharing for both education and valorization of cultural heritage.

The key issues in identifying and applying virtual and digital systems and their implications for education in conservation and valorization of cultural heritage are examined in this paper. The application of virtual simulation for learning or other educational scenarios requires an awareness of how to replicate and simulate numerous and complex behaviors that exist in the real world. Software platforms create interactive 3D content for multiplatform publishing and promote knowledge-sharing communities.

1.2 Tools and design of system - factors and influences

Virtual and Augmented Reality

Virtual Reality (VR) digitally recreates a real-world scenario using a range of software and hardware platforms, Augmented Reality (AR) on the other hand superimposes some of these VR experiences as digital elements in the real world. They are used interchangeably and share some of the same software and hardware technology, but the interactive experience is noticeably different. VR offers the user degrees of freedom, that is it is confined in a computer generated world view while AR provides degrees of freedom in that it uses visual and auditory senses to provide you with sensory information overlaid on the world that you are surrounded in. Virtual Reality utilizes software and hardware platforms to simulate and re-create numerous and complex behaviors that exist in the real world. Sherman and Craig (2003), describe VR as virtual worlds which are constructed in 3D space using computer graphics. This is enhanced by a virtual human presence as an immersive experience with user interaction, navigation and sensory experience with the virtual world and its objects [1]. The continuing evolution of VR computer simulation software has generated lower cost, accessible and more intuitive tools. These tools are now used for the development of AR/VR learning environments [3] [5] [6].

Virtual Heritage - Historic Building Information Modelling.

Building Information Modelling (BIM) is a virtual representation of a building, its structure, materials, and environment, providing the associated information (the "metadata") related to its design, construction and future lifecycle. Historic Building Information Modelling (HBIM) is an extension of BIM for the physical and knowledge management and conservation of architectural heritage.

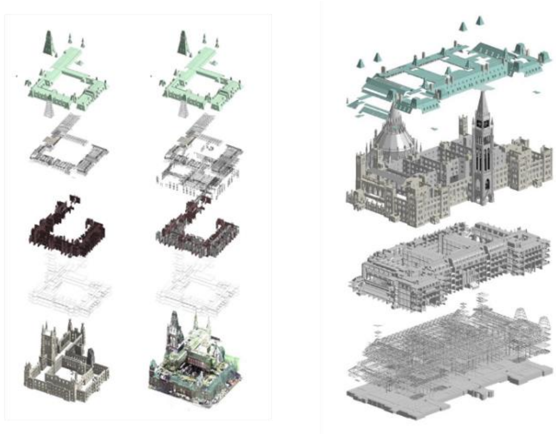

Fig. 2. Scan to HBIM Ottawa Parliament see CIMS

https://cims.carleton.ca/#/projects?projectFilter=All

HBIM involves the digital recording of historical buildings using remote sensing (laser scanning, digital photogrammetry) or combinations of digital surveying and manual techniques. The acquired survey data is then processed improving the data organisation and adding intelligence using BIM software platforms. Because of the difficulties in accurately representing the variety of complex and irregular objects occurring in historic buildings existing BIM libraries of parametric objects need to be rebuilt and coded. In addition, as the building exists and is represented by a remotely sensed model, systems to map the intelligent library objects onto digital or other survey data were also developed. Cultural heritage researchers have recently begun applying Building Information Modelling (BIM) to historic buildings. The intelligent data or information contained in the model can range from geometric and spatial to material, structural, environmental, cultural and economic. Most of the research carried out in past few years was case study-based and was initiated by educational institution in different countries such as Carleton University in Canada. The methodology used by these researchers to develop HBIM involved data collection using laser scanning and modelling historic architectural elements graphically using BIM software platforms (see Figure 2) followed by mapping 3D objects in the point cloud data, [7], [8], [9], [10], [11], [12], [13].

Virtual Heritage - Game Engine Platform.
While BIM platforms have the potential to create a virtual and intelligent representation of a building, its full exploitation and use is restricted to narrow set of expert users with access to costly hardware, software and skills. The testing of open BIM approaches IFCs and the use of game engine platforms is a fundamental component for developing much wider dissemination. The nature of videogame engines is scalable and multiplatform and can potentially be viewed on a variety of systems with different performance capabilities, from tablets to sophisticated virtual reality workstations. Working with large data sets require also, intuitive tools and rapid workflow and capabilities for lighting, mapping and material editors to replicate real world 3D. A packaged 'game file' is designed to execute in a standalone fashion, requiring no additional proprietary software installed on the end-users computer system. In addition, Augmented Reality (AR) and immersive experiences using wearable technology enhance the experience whether for entertainment or education [14].
The virtual worlds are constructed in 3D graphic modelling platforms before they are exported into game engine platforms and only contain geometry and texture and are therefore limited to applications for visualisation. The enhancement of the 3D visualisation model for immersive experience with user interaction is generated within the game engine platform. Intelligent information enhanced models on the other hand facilitate the integration of data from different sources, scales and disciplines into a single cohort model. Exporting a BIM model into a game engine allows for a packaging of BIM data that can be used in a simplified and more intuitive for the user. With regards to educational applications, game engines can give public access to information, places and objects that are usually restricted, virtual models produced can allow for these to be experienced, [15], [16], [17]. Game engines can be applied to make two major contributions to architectural conservation: they can allow a low-cost method of making an HBIM model more easily accessible to actors in the building industry; and they can be used for educational purposes to facilitate dissemination of knowledge of cultural heritage, particularly in museological applications.

2 A Theoretical Design Framework based on Heritage Learning Objects.

2.1 Learning Objects and HBIM.

If Historic Building Information Modelling (BIM) and Game Engine platforms are incorporated into the design for Virtual learning in building conservation, it offers a very different experience from classroom-based learning. The concept of HBIM libraries which are digital objects representing historic architectural elements which are brought together to virtually represent historic structures. In virtual learning environments these libraries become virtual   Similar to object orientated programming, Learning Objects systems (LO) exist as elements or entities in digital format and can be reused as content in WEB based learning environments. Learning Objects systems (LO) exist as elements or entities in digital format and can be reused as content in WEB based learning environments.

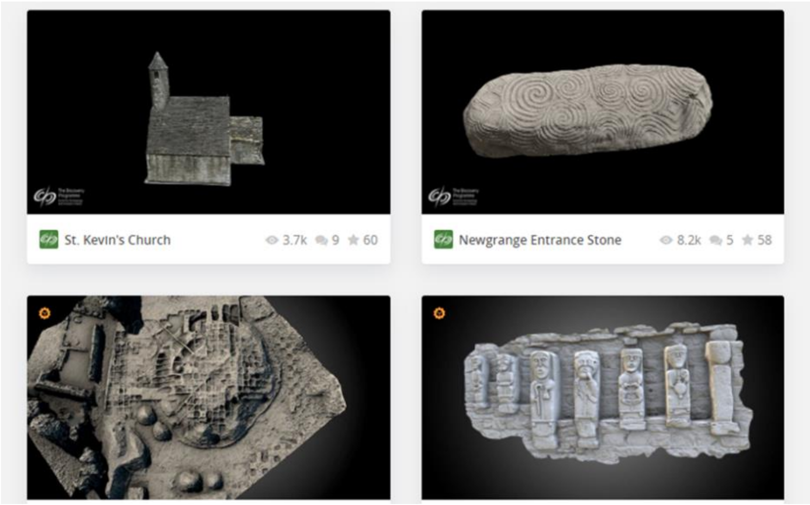

Fig. 3. Digital Heritage available at https://sketchfab.com/discoveryprogramme

In Figure 3 above digital learning objects are available for WEB-based visualization of a large range heritage objects and structures from the EU 3D Icons project. The main computing elements are metadata standards and system specifications such as levels of scale, level of detail of data and cross platform interoperability in this case assisted with the WEB platform SketchFab. In addition to 3D geometry and texture the types of digital resource that can be reused to support learning include images or photos, live data feeds, live or pre-recorded video or audio snippets, text, animations, and web-delivered applications such as a Java applet, a blog, or a web page combining text, images and other media. Learning Objects (LO) as knowledge-based objects are self-contained and reusable and described by their meta-tags which include their history, meaning, quality and destination. LO elements are units which make up the content and the LO can be singular or a combination of elements. The IEEE Learning Object Metadata Standard (IEE) specifies the syntax and semantics of learning object metadata describing levels of detail (aggregation) and learning resource types. The aggregation detail ranges from the smallest elements (raw media data or fragments) to secondly a collection of elements for a lesson, thirdly a collection of lessons or modules for a course and finally a set of courses that lead to a qualification [19] [20] [21].

2.2 Learning Objects - Cognitive Elements.

The cognitive and learning elements are equally important as texture geometry and must be acknowledged in design and delivery of Learning Objects. It is therefore a case of deciding what type/combination of digital resource is used and to what level of detail and scale to correspond with the participants' pace of learning, prior knowledge held and other criteria. The main cognitive elements for LOs are the conceptual structure of the area of learning, the student's aptitudes and the appropriate delivery and assessment systems. Learning is an active process of building rather than acquiring knowledge and instruction is a process of supporting that construction rather than communicating knowledge resulting in learners actively participating in the learning process. Learner inclusion and participation becomes a design fundamental for LO systems through the inclusion of generative learning environments [22], [23], [24].

3 Case Studies

3.1 Case Study - Armagh Observatory

The observatory at Armagh in Northern Ireland was founded in 1790 by the Church of Ireland Archbishop, Richard Robinson as part of his wider scheme to develop the fabric and institutions of the city following a prolonged period of strife and neglect. Students who are studying the module in Building Conservation in the Dublin Institute of Technology undertook the digital recording and 3D CAD modelling of the Observatory. The emphasis is on learning by doing so low-cost accessible recording and modelling tools are used by the students.

In the case of the Armagh Observatory the aim of the proposed project was to create a 3D computer based model of the observatory its instrument positions and the location of the meridian markers by building a virtual terrain model and virtual building model placed in the terrain. The final result as a full virtual model of the building and its markers can then be employed for simulating the instruments in their position in the observatory and earths meridian used to measure declination, the angle between the star and the celestial equator. The buildings, the landscape, the instruments and the night sky replications as Heritage Learning Objects are illustrated in Figure4 and the bottom right hand side of the Figure shows the on-site survey using GPS.

On-site Leaning – The Missing Factor in Virtual Learning.

The fact that the students carried out on-site surveys giving them a tactile real-life experience is missing from the virtual only learning experience. So, it is necessary to replicate as best and include the site experience from documentation of this experience. An example of this on-site learning allowed students to apply their theoretical knowledge from the classroom to practice by appreciating the various steps and potential errors arising when recording and processing GPS data. Data was collected in the WGS84 geodetic coordinate system using a GNSS receiver in Network Real-Time Kinematic (NRTK) mode. In NRTK mode, the GNSS receiver requires a connection through a mobile connection to a network of fixed base stations to correct in real-time for major sources of errors. Several measurements were recorded at each point of interest along the Meridian's line, In most cases, observation could only be recorded at the base of the monuments or on positions estimated as being as close as possible to the alignment of the Meridian. Where issues related to poor mobile network connection or poor satellite geometry arose (in particular when measurements were taken too close to a building or monument), observations were subsequently removed. All data collected was then exported from the data logger and the GNSS data was converted to the Irish National Grid.

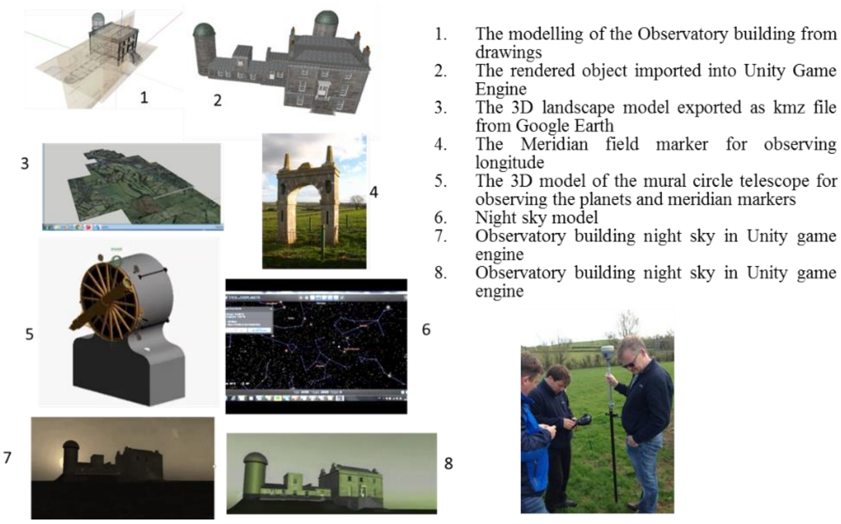

Fig. 4. The Pilot Model Virtual Replication of Armagh Observatory

3.2 Virtual Learning Objects as a Shape Grammar for Archaeology

In figure 5, below a shape grammar is developed for reconstructing the Romanesque door case of a 12th century Irish church, Kilmalkeader. The grammar learning objects are based on the remaining elements of the door-case from laser scan and traditional surveys and interviews with archaeological experts. The grammar initially develops the primitives for the opening of the archway and columns. The Romanesque carving and the complexity of the stones making up the arch are determined from a Boolean operation production rules based on the non- terminal shape on the bottom left through to the terminal block shape with carvings. The virtual replication of the door-case and structure is mainly achieved by converting the laser scan and photogrammetric data to solid

3D models. The replication of complex geometries and shapes require authenticity and accuracy for digital reconstruction can also be an evolved process as more information comes to light.

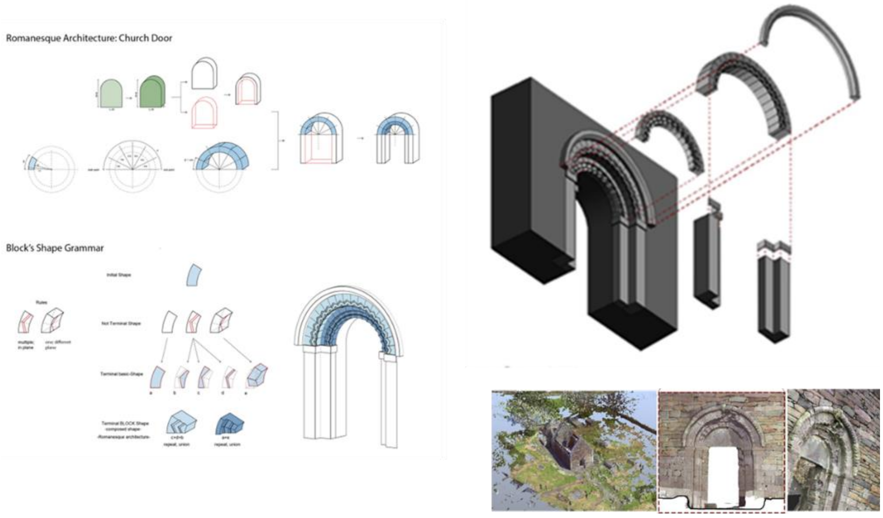

Fig. 5. Shape Grammar for Romanesque Door-case, Exploded Model of Door-Case and Scan Survey

3.3 Virtual Historic Dublin – Interaction with Heritage Learning Objects

In this case study interaction with the Heritage Los are introduced using game engine software platforms. Virtual Historic Dublin is a dynamic digital repository and portal based on modelling an Lidar scan of the historic center of Dublin City. The combination of digital recording, modelling and data management systems enable the interaction with complex, interlinked three-dimensional structures containing rich and diverse underlying data. End users can encompass architectural and engineering conservation, education and research, in addition to public engagement and cultural tourism. Two major aerial based 3D mapping surveys which were carried by the School of Engineering UCD in 2008 and 2015 and funded by Science Foundation of Ireland and European Research Council (1.8 Million Euros). The survey data includes most of Dublin City's medieval and classical historic areas.

Irish Parliament Game Engine Interpretation.
As part of the Virtual Historic Dublin, the Historic BIM model of the Irish Parliament building and complementary digital assets were imported into Unity 3D, Unreal Engine 4, and Twinmotion. HBIM model was exported from Autodesk Revit as an FBX file. Although the FBX format is standard in game design, many other file formats are usable

in game engines. The imported assets retain their groups, families, and texture maps; however, materials often do not transfer over. This can be corrected by baking materials as textures or by remapping assets with new materials inside the game engines. Assets can also be reloaded if changes need to be made. Updated models maintain material adjustments, location, and script attachments. Architectural Visualization platforms and game engines have different uses for dissemination. Visualization programs provide easy to use curated tools for model showcasing and video creation while game engines facilitate purpose-built interactions. Despite the interactivity limitations of arch-vis tools, Twinmotion still serves as an effective platform for model viewing. The application's BIMmotion feature allows user to explore digital models with navigation capabilities, VR compatibility, and video attachments through a standalone executable file. With any game engine there is more freedom to build custom interactive experiences, industry standard game engines carry extensive toolboxes for terrain editing, physics simulation, animation, advanced lighting and for VR/AR, and real-time rendering. For the Timeline application, the conceptualized features were prototyped in Unity with five historic map models. The Unity game engine was chosen to develop the timeline application because of its quality rendering accessibility, asset store, and reputation. Unity also has a large community of independent game developers and plenty of online tutorials, forums, and open source scripts for basic video game features.
Figure 13: Morphology Evolution Irish Parliament

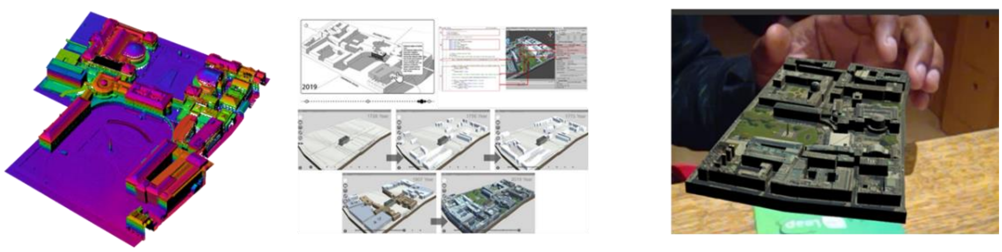

Fig. 6. Irish Parliament - Leinster House, Aerial Scan and HBIM model imported into Unity Game Engine Platform and Morphology Evolution Irish Parliament - Leinster House, Augmented Virtual Reality – Virtual Historic City

4 Conclusion

The Figure below is adapted from the work of Graff 2007 [24] and can be applied to cultural heritage for design of Virtual learning Environments (VLEs). Like most systems, technical requirements are software and hardware based but then link into the requirements of teaching from simple active linear text, general 3D models, vision maps, videos, animations, chat, forum and emails and navigation to more complex virtual reality. Technology will allow synchronous, or real-time, communication which takes place like a conversation, which is the concern of the teacher. Asynchronous, takes place outside of real-time, is the concern of both teaching and pedagogic content. The user is very concerned with ability of the system to be user friendly in ease of delivering and teaching the student. While the application of Information and Communication Technologies ICT can supply VLEs the development and adaptation of Virtual Reality with VLEs can give the impression to the learner of being there whether it is the classroom, the lab or the heritage site. This is described as Immersive learning and with novelty and innovation introduced using both Virtual Reality and Augmented Virtual Reality in game engine platforms the experience of the user can be further enhanced to create a perceived immersed learning experience.

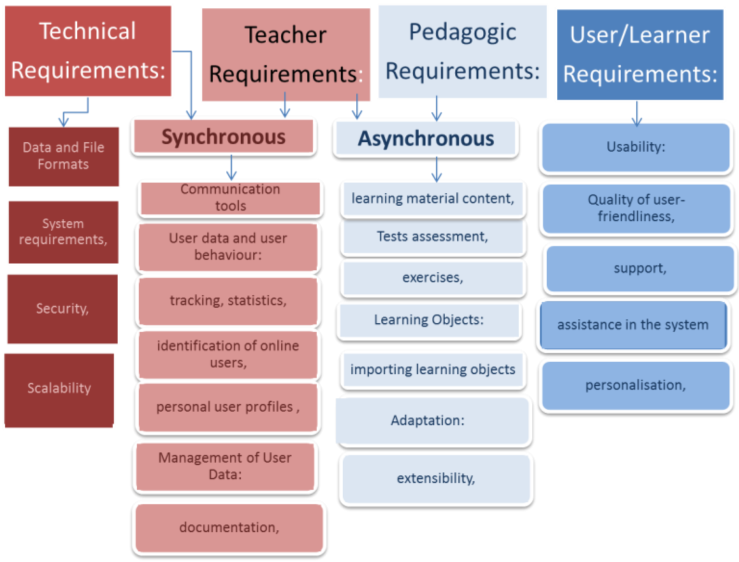

Fig. 7. Design of Virtual Learning Environments for Cultural Heritage

Generic Influential Factors and Causalities for Heritage Virtual Learning Environments.

Like other sectors, Heritage Virtual Learning Environments are also subject to rapidly evolving software and hardware systems. The influence of technology learning systems is also related to learner digital media literacy and changing attitudes of the traditional lecturer/researcher from a mental concept of; 'what has always worked', to embracing virtual learning technology. New influences must be capable of providing the supports and services needed to enable students engage with the subject on a deep level and educator's time to learn how to harness these learning systems. Design factors for learning systems should include: (i) expanding access and convenience; noting the challenges with disparities in digital infrastructure and learner to learner engagement between groups, (ii) fostering authentic learning; noting how including activity based learning such as problem based learning and replacing on-site experience with other models will ensure learners are active contributors to their knowledge and learning

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